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ABSTRACT

This study of gender differences in mathematics learning examined two 4-year-olds who attended a Melbourne, Australia preschool. The study traces the experiences of the students, one female and one male, during their first formal exposure to mathematics in kindergarten. Of particular concern was how the preschoolers interacted with their teacher, the ways in which the students processed the explanations of important mathematical concepts given by the teacher, and the ways in which they approached and handled unfamiliar mathematical problems. Research has indicated that teachers often interact differently with their male and female students, with males attracting more interactions. Findings showed substantial differences in the students' involvement during relatively formal, teacher-led sessions concerned with exploring and developing mathematical concepts. The students differed in their response to teacher questions and their patterns of offering unsolicited comments or initiating interactions with the teacher. As a result, the male student's visibility was higher than the female's. The teacher's mode of instruction contributed to higher male visibility and to the provision of opportunities to confirm or challenge students' emerging understandings. (SH)

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Early school experiences: gender differences in mathematics learning.

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Early school experiences: Gender differences in mathematics learning

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Introduction

Gender differences in mathematics learning continue to be a matter of concern in many countries - to researchers as well as practitioners, school systems, administrators, and governments. A number of small but consistent differences between groups of females and males have been described in the literature in performance in public examinations and large scale testings, with significant differences generally favouring males. Somewhat greater differences in long term participation in mathematics and related fields have also been reported (Leder, 1990a; in press).

The consequences of these findings are far reaching and compounding. For the small differences in performance and participation rates are often accompanied by subtle differences in the ways females and males regard themselves, and are regarded by others, as learners of mathematics (Fennema & Leder, 1990). Students who believe that studying mathematics is not appropriate for them, even though they are capable of doing so, are more likely to self select out of mathematics courses and hence out of other areas for which such work is a prerequisite.

A large number of explanations have been put forward to account for the observed gender differences in mathematics learning. Models particularly useful to educators have been proposed by Eccles, Adler, Futterman, Goff, Kaczala, Meece, and Midgley (1985); Ethington and Wolfle (1985); Fennema and Peterson (1985); Leder (1986); and Reyes and Stanic (1988). These models have a number of features in common: the emphasis on the social environment, the influence of significant others in that environment, students' reactions to the cultural and more immediate context in which learning takes place, the cultural and personal values placed on that learning and the inclusion of learner related affective as well as cognitive variables.

The ways in which teachers and students engage inside the classroom cuts across a number of these dimensions. Research has indicated that teachers often interact differently with their male and female students, with males attracting more and qualitatively different interactions. Evidence for this assertion in mathematics classes has been provided by, among others, Becker (1981), Brophy (1985), Eccles and Blumenfeld (1985), Koehler (1990), and Peterson and Fennema (1985) for American classrooms; Galton, Simon, and Croll (1980) and Walden and Walkerdine (1985) for British classrooms; and Dunkin and Doenau (1982) and Leder (1987; 1990b) for Australian classrooms. Comparable data have also been reported by Staberg (1985) for Swedish classrooms. The samples in these studies were either elementary or high school students.

The research reported in this paper traces the experiences of two able students, one female and one male, during their first formal exposures to mathematics at kindergarten.[1] How these young pre-schoolers interacted with their teacher during these more formal sessions was of particular concern. Emphasis was placed on the ways in which the students processed the explanations of important mathematical concepts given by the teacher and on the ways in which they approached and handled unfamiliar mathematical problems. Information was also sought about the children's home background, personal characteristics, and learning environment at home and in particular at the pre-school.

Method

Subjects

The students of interest, Margaret and William, attended a pre-school in a middle class suburb in the metropolitan area of Melbourne four half days each week. They were in the 'four-year-old' group, i.e. the group of children who would be four by June 30th of that year. (Detailed observations were in fact carried out on four other children in the pre-school. These data provided an important context against which the information gathered on the children of particular interest could be assessed).

The setting

The teachers working at the pre-school considered that

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[1] In the Australian state of Victoria, children start formal schooling in the year in which they are at least 4 years and 6 months on 1 January.

the main aims of the program they delivered to the children were to foster social development, to facilitate the development of language as an effective means of communication, and to expose the children to music, movement, mathematics, science and art experiences. The mathematical activities were often introduced in segments, usually of between 15 to 30 minutes duration, of teacher-lead instruction to a small group of students. Typically, Margaret and William were placed in the same group during these sessions.

Procedure

A variety of data gathering methods was used. The children were observed regularly: on at least three out of the four sessions they attended the pre-school each week. A selection of the more formal teaching sessions which focused on mathematical concepts were video taped so that the students' learning environment could be monitored and so that they could be interviewed readily in a one-to-one setting about the activities discussed. These tapes were subsequently transcribed and analyzed to allow detailed descriptions to be made of the students' behaviours during the teaching segments. A variety of observation schedules, both quantitative and qualitative, was used for this purpose. Of particular interest were those used by Brophy and Good (1974), Delamont (1983), Meehan (1979), Rowe (1974), and Voigt (1985). The students' behaviours in novel settings, requiring mathematical skills and introduced as play activities, were also assessed.

Data on the students' home backgrounds were gathered

through questionnaires, through interviews with their mothers, both at the pre-school and in the home, and by asking the parents to keep, for one week, a detailed diary of the activities in which their children were involved.

The academic year in Victoria, the state in which the study was carried out, consists of four terms. Data were gathered in all but the first of these.

Results

General background information

Interviews with the parents of the two children revealed many similarities in their background. Both had one younger sibling of the same sex as themselves. Both had well educated parents. William's mother was a scientist working part time for a large scientific organization, while Margaret's mother had been a secondary science teacher who was now studying part-time and working part-time as a research assistant at a nearby university. The fathers of both children also had formal tertiary qualifications and occupations which required such an academic background.

The pre-school had an open door policy to the parents. All the parents we interviewed felt they had a good appreciation of what the program aimed to achieve. William's mother described its thrust as follows:

> It's very much freer here, compared with the kindergartens the children of my friends attend. [At the others] there seems to be an expectation that each child has to bring home something each day and that it has to look reasonable .... They seem to be more regimented. If it's morning tea all the children sit down together and when they are finished they all go on to the next activity together .... It's predictable: cooking if it's Friday, and Mondays ... As I said, it's very much

> freer here and it's been really good, because one of the things William was not good at was running around and climbing. [The teacher] has really opened him up there. He now runs around, runs along the beam and over obstacle courses .... I realize now that this making of things was not as essential as I thought. And I don't think they should learn to read.

Margaret's mother described the role of the pre-school in her child's education in much the same way:

> ... largely social activities. Learning to be part of a larger group. Being introduced to things in a different way than I'd introduced them, to a broader range of things than I might use. Working with adults. Teaching them independence. I don't see it now in an academic role .... Last year Margaret went to a kindergarten for three-year olds. She seemed to enjoy it and the people there were very nice. But I didn't feel that it was very stimulating. I like the freedom that they get [with this teacher] to use their imagination, the lack of guidance, in a way, that creates its own independence.

Indeed, both mothers indicated that they wished their children to be curious about their environment, to learn to adapt to it, and to become independent learners.

Margaret was encouraged to go to the shop and buy small items by herself. She frequently played with lego, liked measuring items, enjoyed playing in the sand pit, with water, and on the outdoor play equipment that stood in the family's back garden. She often set the table by herself, and helped with meal preparation. For example, she knew how to measure half, one quarter and three quarters of a cup of ingredients. Margaret's mother used opportunities for informal teaching as they arose. Thus a trip to the airport was used as an occasion to discuss time zones, the volume of traffic going into the city at different times of the day, and the

importance of labelling luggage so that at the end of the journey suitcases could be matched with their owners.

William's mother described her role in her son's development and education as one of facilitator. She stressed her commitment to discussing and explaining events as they arose and emphasized the importance of showing her child where to find information.

> I often tell him I don't know. He is now learning that if we go to the library and go into the children's reference section we can find a book on the subject.

William often played in the sandpit in the backyard and loved riding his bike. He also liked playing with lego, spent time cutting and pasting, and helped in the kitchen. He was encouraged to make selected dishes by himself. The home contained a rich store of well used books, games, and toys. Family outings were a high priority.

The parents of both children subtly monitored the television programs watched by their children. Diaries kept over a typical week to monitor activities in the home indicated that the children watched equivalent amounts of television: approximately seven hours for the week. In contrast, some of the other children surveyed at the same pre-school watched over 25 hours of television per week.

Academic background

The students were tested formally in three different ways: using the Peabody Picture Vocabulary test (Dunn & Dunn, 1981), the Frankston Concept test - a slightly simplified version of the Boehm Concept test (Boehm, 1971) - and the

Keymath test (Connolly, Nachtman, & Pritchett, 1976). William and Margaret tested at the 97th and 94th percentiles respectively on the first of these tests, and at the 95th and 99th percentiles respectively on the Concept test. Their grade scores on the Keymath test were 1.5 and 0.9 respectively.

Other observations put these scores in context. Both Margaret and William, but not all the children in their group, were able to apply and discuss in some detail the concepts developed during the more formal sessions. These included grouping objects according to attributes, descriptors of quantity, size, measurement with respect to length, weight, volume, and time, rote counting to at least 10, and one-to-one correspondence to at least five. They could use and recognize symbolic representations of small groups of objects (Leder, 1989) and managed to solve mathematical problems presented in a play setting and which involved, for example, working out that nine lollies were required if three were to be given to three children, or that two more books were required if each child in the group of four were to have two books but only six had been borrowed from the library. Typically, they were also able to produce meaningful written symbolic or pictorial representations of these situations. Such problems were considerably more demanding than those covered either formally or informally in the pre-school program and were not able to be solved by many of the other children who attended the kindergarten.

<u>The formal sessions</u>

Observations of Margaret and William during the formal teaching sessions suggested that there were a number of differences in the way the two students participated in the lessons and were reinforced for their behaviours by the teacher. In this section these differences are described in some detail.

The data presented are based on the observations gathered during two formal teaching sessions given half way through the year: the fourth and fifth sessions out of a total of nine monitored over the year. For both these sessions Margaret and William sat facing the camera. Thus both verbal and non verbal responses could be examined in detail.

Lesson 1

In the first of the two teaching episodes to be described the teacher worked with a group of 10 students, six boys and four girls, for approximately 30 minutes. She focused on the concepts of 'a few' and 'many'. The session was dominated by teacher talk: she spoke for approximately seventeen and a half minutes altogether. During this time Margaret responded to 23 of the teachers questions or directives, William to 34. In addition the teacher responded to two out of the five comments or actions initiated by Margaret and four of the ten begun by William. While the former had two sustained exchanges with the teacher, William had eight such exchanges. Aspects of the interactions are described more fully in Table 1. The categories are the same as those used by Mehan (1979), except that the categories of low and high cognitive level questions are used instead of product and process designations.

Table 1:

Summary of interactions with Margaret (M) and William (W) Lesson 1.

	Turn Allocation				Procedure			
Teacher's Speech Acts	Individual Nomination		Invitation to bid		Invitation to reply		Other	
	M	W	M	W	M	W	M	W
Directive							3	2
Choice elicitation		1			4	3		
low cognitive elicitation	3	4			7	23		
high cognitive elicitation					3	1		
meta process elicitation								
other							3	
Student's unsolicitated comments:								
acknowledged							2*	4
ignored							3	6

* One of these was in fact an unsolicited activity, for which Margaret was reprimanded by the teacher.

The data indicate that the teacher often addressed questions to the group in general, though at times she called on individual children. William was specifically asked five questions, Margaret three. The former elected to answer 27 of the 'group' questions, Margaret 14. Many of the sustained exchanges William had with the teacher were achieved in this

way. Interestingly, Margaret volunteered a response to three of the very small number of high cognitive level questions asked during this session, William to only one. Further analysis of the transcript of the lesson revealed that the teacher acknowledged 21 out of the 32 cognitive responses (66%) made by William to questions initiated by her and 10 out of the 17 (59%) made by Margaret.

When all cognitive responses (ie both teacher and student initiated) were combined, Margaret received positive feedback for 10 of her answers; negative feedback for one. During the same lesson, William received positive feedback for 19 cognitive responses; negative feedback for two.

Several excerpts from the lesson are reproduced below, supplemented with relevant comments, to illustrate the different ways in which the teacher responded to the two students. Her different reactions to William's and Margaret's unsolicited comments reproduced in excerpts 2 and 3 respectively are particularly noteworthy.

Excerpt 1

Initiation	Reply	Evaluation	Comment
T: Can you remember which was the smallest group	M: Terry & Sean		Margaret's response ignored by teacher.
T: Which was the smallest group? Which group had the least number of people in it?	W: Sean & Terry	T: right	Same answer as Margaret, this time accepted by teacher.

T: Which group had the most people in it?	W:Boys(unclear) had six	T: No, we're talking about their shoes.	William's response acknowledged and rejected by teacher.
T: Which group the most people in it?			Teacher had moves on to another student.

Excerpt 2

Initiation	Reply	Evaluation	Comment
T: OK, where have you been where there have only been a few people	M: At my house	T: At your house there's just a few people?	Margaret's response acknowledged by teacher.
	M: nods		
W: At my house there used to be four. 'cause my Dad's gone away, now there are just three		T: That's right. Your Dad's on a trip.	William's unsolicited answer is acknowledged & accepted by teacher.
T: When he gets back though, there'll be ...?	W: Four (and puts up four fingers)	T:So there's a few in your house	William's reply is acknowledged by teacher.

Excerpt 3

Initiation	Reply	Evaluation	Comment
T: How many bricks have you got Jeremy.	J: Four(he has three)	Show me please	
	J: Four.		
T: You count them for me.	J:1,2,3,4, (counts the first one twice)	M: No. 1,2,3, (points to the bricks as she counts)	Margaret's intervention is not acknowledged by teacher.

T: How many do you have.	J: No. 1,2,4, (points as he counts)		
M: I'll show you how many is four (put's one of her blocks with Js,3) Look,1,2,3,4,(takes away one). So thats three now.(leaves J with three).		T: Excuse me, Margaret. I have asked J to show me his group.	Eventually she is disciplined for her unsolicited actions

Lesson 2

On this occasion the teacher worked with a group of eight students, four girls and four boys. The session was shorter than the previous one, lasted for approximately a quarter of an hour, and was concerned with the concepts of 'big' and 'small'. Once again there was much teacher talk: just under 7 minutes out of the 15.

William and Margaret responded to 26 and 12 questions respectively out of those asked by the teacher. She acknowledged 10 out of the 19 questions or comments initiated by William and two out of the six initiated by Margaret. During this teaching session Margaret had three sustained exchanges with the teacher, William five. Further details of the interactions are summarised in Table 2.

Table 2:
Summary of interactions with Margaret (M) and William (W) Lesson 2.

	Turn Allocation				Procedure			
Teacher's Speech Acts	Individual Nomination		Invitation to bid		Invitation to reply		Other	
	M	W	M	W	M	W	M	W
Directive								
Choice elicitation		1				3		
low cognitive elicitation	3	2			4	12		
high cognitive elicitation	1				4	8		
meta process elicitation								
other								
Students' unsolicited comments								
acknowledged							2	10
ignored							4	9

The teacher's tendency to invite answers to her questions, rather than nominate specific children, noted in the first of the lessons described was repeated here. She addressed three questions specifically to William, four to Margaret. In addition William elected to respond to 23 of the question asked by the teacher to the group in general, Margaret to eight. Fourteen of the 26 cognitive responses (54%) made by William to questions initiated by the teacher and seven out of the 12 (58%) made by Margaret were

acknowledged by the teacher. When both teacher and student initiated cognitive interactions were combined, William again received positive feedback for approximately twice as many answers as Margaret (15 v.7). Neither student was given negative feedback to a cognitive response during this lesson.

In both lessons there was little difference in the number of responses which received and did not receive teacher feedback. In lesson 1, 17 of William's and 10 of Margaret's responses received no feedback. For the second teaching segment the corresponding figures were 15 and 7. None of the teacher's replies contained attributional statements.

The relatively large number of process or high cognitive level 'why' questions asked in this lesson is noteworthy. All except one of these elicited a low cognitive response, as is reflected in excerpt 4. The teacher's repetition of the 'why' question, seen once in this excerpt, occurred fairly frequently and helps explain her relatively low level of feedback on cognitive responses to the students in this lesson.

Excerpt 4

Initiation	Reply	Evaluation	Comment
T: The bears .. one was big .., he grew, he got to a stage where he just stayed big. One was small.			
M: I know			Unsolicited comment ignored by teacher.

T: Why was that one small?	M: Because it was the mother bear.		High cognitive elicitation, Low cognitive response, no clear acknowledg-ment.
T: And why does she have to be small?	W: I know because the Dads are big and Mothers are little.	Are they? Dads are big...?	Question repeated, answer offered by William is accepted by teacher whose response is interrupted by William.
W: And Mums are that big I think (uses his hands to show what he means)	T: and mummies are little.		
T: Why do you think Margaret?	M: Because, um, Mummies are middle size.	Are they? Well, all right.	Teacher returns to Margaret. Her high cognitive level question elicits a low cognitive level response from Margaret which is accepted.
T: What do you think Daniel...			

This excerpt also illustrates the way in which William frequently gained access to the floor. This time the teacher

returned her attention to Margaret. Frequently, however, William was successful in deflecting the teacher's attention to himself. Such a sequence is shown in excerpt 5, as well as in excerpt 1 reproduced earlier.

Excerpt 5

Initiation	Reply	Evaluation	Comment
T:Daniel, who is the smallest in your family?	D: My dog. My dog is five.	T: But I want to know who is the smallest person in your family	
W: I suppose Daniel	T: Right. He supposed right.		William's unsolicited answer to a question addressed to Daniel is accepted...
T: How do you know?	W: He looks a bit small.	T: Yes, we can tell by looking at him.	and is followed by one addressed to William himself.
T:Margaret, who's the smallest in your family.	M: Heather	Right	
T: Will she always be the smallest?	W: No M: She will grow as big as me.	T: Mm	Even though the question is clearly addressed to Margaret, William volunteers an answer.
T:Will she grow as big as Mum?			Before Margaret can answer William adds:

W: And Ros (the teacher)		T:(nods) Yes, she might grow as big as me.
T: William, who is the smallest in your family.	W: Robert	T: Yes, your young brother.

Discussion

There were considerable similarities in the home background, previous experiences with mathematically relevant activities, and performance on both formal and informal measures of mathematics achievement for Margaret and William, the two students who were the focus of this investigation. Yet there were substantial differences in their obvious involvement during relatively formal teacher led sessions concerned with exploring and developing mathematical concepts.

The students' patterns of offering unsolicited comments or initiating interactions with the teacher were uneven. William and Margaret also differed in their willingness to respond to teacher questions that invited a reply. As a result, while both students actively participated during the two teaching segments described, William's visibility was considerably higher than Margaret's. Undoubtedly, the teacher's mode of instruction - minimizing the number of questions specifically addressed to individual students and relying heavily on student participation through questions

addressed to the group in general - contributed to this.

There were no differences in the proportion of answers given by the two students which received and did not receive teacher feedback. However, because of the much greater number of answers offered by William he received feedback, largely positive, for approximately twice as many cognitive responses as did Margaret.

The teacher also tended to be more accepting of William's than Margaret's interjections and initiatives. In particular, Margaret was rebuked for a potentially constructive initiative shown by her - to work with another student, help him count his number of blocks, and demonstrate why his response was incorrect. This episode, and a similar interaction between the two students later in the lesson gave rise to the only disciplinary comments given by the teacher to either Margaret or William during the two sessions. Thus, whereas William's unsolicited comments, answers to questions addressed to other students, or embelishments of answers given by other students were often accepted by the teacher and led to constructive interactions between the two, Margaret's offer to help another student by modelling and explaining the task set by the teacher was firmly rejected and censured by her. The excerpts included as part of the descriptons of the teaching segments revealed that William's attempts to dominate the discussion were often successful. The teacher seemed less accepting of Margaret's unsolicited contributions. William was able to influence the direction and content of the lesson on a number of occasions, Margaret was not.

The results presented have highlighted differences in the early formal learning environment of two students, one boy and one girl, whose academic qualities, home experiences and expectations showed much overlap. It is beyond the scope of the present study to determine the long term effects on mathematics learning of the differences in the students' formal learning environment discussed in this paper. There seems no doubt, however, of the role played by the classroom teacher in contributing to the differences in classroom climate experienced by the two, including opportunities to have their emerging understandings confirmed or challenged. The data presented confirm the assertions of those who cite environmental factors as crucial to the understanding of gender differences in mathematics achievement.

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